DOCUMENT RESUME

ED 224 461 IR 010 491

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TITLE An Evaluative Study of the Effects and Effectiveness of Microcomputer Based Teaching in Schools.
INSTITUTION Leeds Univ. (England).
SPONS AGENCY Social Science Research Council, London (England).
PUB DATE Jan 82
NOTE 52p.
AVAILABLE FROM J. R. Hartley, Computer Based Learning Unit, University of Leeds, Leeds LS2 9JT, Yorkshire, UK (1 British pound plus postage).
PUB TYPE Reports - Research/Technical (143) -- Tests/Evaluation Instruments (160)

EDRS PRICE MF01/PC03 Plus Postage.
DESCRIPTORS *Computer Assisted Instruction; *Computer Programs; Decision Making; *Evaluation Criteria; Foreign Countries; *Instructional Materials; Interviews; *Microcomputers; Program Effectiveness; Questionnaires; Secondary Education; Secondary School Teachers; *Teacher Attitudes; Use Studies
IDENTIFIERS Great Britain; Microelectronics Education Programme

ABSTRACT

Secondary teachers' evaluation and classroom utilization of computer assisted instruction (CAI) packages were studied. Following selection of 91 CAI programs in math, science, geography, and economics, teachers in four secondary schools examined and, where appropriate, used the programs in classrooom teaching. Teachers' opinions and judgments were collected using interviews and questionnaires. Although 28 programs were judged to be of interest, only 15 programs were used. Data were collected from 22 lessons during a 6-month period using classroom observation schedules, pupil questionnaires, and teacher interviews. Though the programs were judged effective, difficulties in pupil pretraining and class administration were often underestimated. An extensive evaluative study was undertaken in one school, with 14 classes using math programs and 6 microcomputers. Posttest results favored CAI groups, though not significantly. Overall, the project showed initial interest in CAI, but indicated the need to maintain interest through relevant program/curriculum developments, appropriate training courses, and complementary research programs. This study report includes 15 references and 3 appendices containing a list of available CAI programs, data collection instruments, and a summary of the classroom interaction scheme. (LMM)

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AN EVALUATIVE STUDY OF THE EFFECTS AND EFFECTIVENESS OF MICROCOMPUTER BASED TEACHING IN SCHOOLS

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January 1982

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ABSTRACT

Interest in using Computer Assisted Learning (CAL) within Secondary Education has been stimulated by developments in microcomputing, and by the National Microelectronics Education Programme (MEP) set up by the Department of Education and Science. However, previous experience suggests that the design and production of high quality CAL materials and their integration within conventional teaching methods will not prove easy. The aims of this research were to study teachers' assessments of current educational programs, the decisions which guided their application in the classroom, the influence of these materials on learning activities, and what teachers themselves learnt from the experience.

Ninety-one CAL programs suitable for school use were obtained from publishers and from other sources. They were adapted to run on 380Z and North Star microcomputers (and some on Apple II machines); documentation was prepared so that teachers could access and use any of the programs which covered subject areas of Mathematics, Science, Geography, and Economics. Four local schools were the principal participants in this study and their staff agreed to examine and to use the programs, where they could, in classroom teaching.

Teachers' opinions and judgements of the CAL materials were collected by interviews, and by questionnaires which required both rating and open-ended responses; over one-hundred staff examined the materials. This scrutiny resulted in some dampening of enthusiasm, but overall twenty-eight of the ninety-one programs proved to be of interest. The questionnaire data showed teachers to be particularly concerned with the relevance of the programs to their courses, the flexibility for suiting different modes of teaching and degrees of user sophistication, and the presentation of feedback and data at the terminal.

These criteria were even more prominent when teachers were deciding on the use of the CAL materials in the classroom, and

over a six-month period only fifteen programs were taken up. Ten of these were from the published list and five produced locally. Twenty-two lessons were observed, and data collected through a classroom observation schedule which described educational interactions in terms of the cognitive processing they required or drew from the learner. Pupil questionnaires were used and pre- and post-questionnaire/interviews were held with teachers. Initially, one microcomputer was made available for a class, with the option of an increase to a cluster of three.

In planning their lessons and judging the effects and effectiveness of the CAL programs, the teachers' prime concern was the interaction between the pupil and the CAL materials. Although evidence of learning through tests, homework assignments and performance in class questioning was important, the immediate judgement was given to the interest the program aroused, the questions it drew from the pupil (or pupil groups) and the opportunities it provided for development and supporting instruction. Teachers tried to allow hands-on experience through group work with clusters of microcomputers and, where possible, arranging for these to be available in lunchtime and after school. The observation data showed the programs created good interest levels in the classes, but the working methods of groups were important if the less able pupils were to benefit. Some of these learners were not able to develop conclusions from the simulation type programs which thus became mere providers of data. Overall teachers did not break new ground but used the programs to consolidate principles they had covered before in the lesson. If this pre-teaching were too direct then the CAL exercise became one of **comprehension** and the interaction analysis scheme indicated that this was a prominent category. All the teachers, except one, judged the programs to be effective and would use them again in their instructional schemes. However, teaching staff tended to underestimate difficulties in the pre-training of pupils and in class administration.

An extensive evaluative study was undertaken in one school where, for the duration of the experiment, a laboratory of six microcomputers was established. The subject area was Mathematics (straight-line graphical functions), and over three-hundred pupils and eight members of the teaching staff were involved. Of the fourteen classes who participated, eight used CAL programs which were written by the research team to specifications provided by the teachers: the remaining six were taught conventionally. All the classes were given the same instructional time, and covered the same content in the same sequence using the same worksheets. The experiment lasted three-to-four weeks. Post-test results favoured the CAL groups, but did not reach statistical significance. The gains were probably not more pronounced because the programs were restricted in design and application to follow the normal teaching methods and worksheets. The observation schedule again showed good levels of interest in the CAL classes, and

teachers considered that the opportunities provided by the programs in allowing staff to monitor and question pupil groups was a significant advantage. Overall, teachers judged the experiment to be successful and have since repeated the exercise in another area of Mathematics.

The research work has been reported in journals and disseminated through conferences and seminars. A three-day residential course in CAL was organised for schoolteachers from five Local Authorities in the Yorkshire region, and a two-year part-time Advanced Diploma course in 'Computers in (school) education' has been established at Leeds University and its first students were admitted in October 1981.

Overall, the project showed there was much initial interest in micro-CAL, but this can easily wane and has to be secured through relevant program/curriculum developments and appropriate training courses. These are the functions to be undertaken by the Microelectronics Education Programme (MEP), but this study suggests that such activities will need to be informed and stimulated by a complementary and coordinated research programme if significant learning benefits are to result.

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1. AIMS OF THE RESEARCH

Developments in microelectronics have brought Computer Assisted Learning (CAL) within the financial and educational aspirations of schools, and this innovation is being stimulated by grants from the Department of Industry and from the DES Microelectronics Education Programme (MEP). However the active interests of schoolteachers are likely to encounter significant problems. At present, available materials can be uneven in their relevance to the curriculum, in their coverage and in their quality; CAL programs are not easy to integrate within conventional teaching schemes, particularly when the number of microcomputers available for class use is limited. Further, most teachers are unfamiliar with the technology and there have been few evaluative studies to guide method and decision-making.

Any research into the effects and effectiveness of microcomputer-based teaching in schools must be set against this background. The aims of this particular study were to examine teachers' views and expectations of CAL and its programs, and the ways they assimilate these materials within their classroom practices. Questions asked included: Which programs create interest, and for what reasons? What learning functions and responsibilities are given to microcomputer based packages, and what are their effects on student activity and learning? On what basis do teachers make instructional decisions, and what are their criteria for judging success? What data subsequently change or confirm their opinions? It was expected that evidence obtained would indicate the training and technical support needed by teachers working with microcomputers, and point to the research required to guide further developments such as program design and modes of utilisation.

2. A REFERENCE TO PREVIOUS CAL RESEARCH AND DEVELOPMENT

Although there is relatively little reported research evaluating the use of microcomputers in schools, the experience of the National Development Programme in CAL (NDPCAL) funded by DES from 1972-77, is relevant. Admittedly, most of its projects were set in Higher Education and based on mainframe computers; universities and polytechnics have greater resources than schools, their teachers have more direct control of the curriculum and students have more time for individual learning. Nevertheless NDPCAL projects had to answer many of the questions specified above.

2.1 The development of CAL materials

Reports appraising the National Programme (eg. Hooper 1977, Hartley 1978) show that the roles assigned to CAL and the designs of its programs came directly from an analysis of teaching/learning situations - perhaps where conventional methods were limited or were not doing well. In contrast many of the programs currently published for microcomputers seem to lack this analysis, and to have been developed without close reference to the requirements or the difficulties in teaching/learning the subject area.

Another feature of NDPCAL was the variety in the types of materials which were required. They included adaptive tutoring, learner control systems, simulation packages, modelling through programming languages, educational data-bases, question banks, problem solving/decision making programs, and computer managed instructional schemes. For producing these a variety of languages were used. It is unfair to make comparisons between this diversity and the limited amount and types of materials and software which are currently available for schools. However, this must cause schoolteachers to be restricted in their educational ambitions.

During the last two or three years a variety of publications (eg. Computer Education, Educational Computing, Computers in Schools) has been produced to inform and stimulate the use of computers in school education. Also, large development projects such as ITMA circulate their own newsletters [Wells (editor from 1979)]: the Association for Microcomputer Use in School Education (MUSE) acts as an information centre, and makes available to its members programs which have been produced in schools. [The research team became members of MUSE at the start of the Project.] Other main sources of programs are publishing houses and the Central Program Exchange scheme.

Most of these current programs are small in size, of the calculation/simulation type, and written in some version of BASIC. The subject areas are biased towards science and mathematics, but include some topics in geography and economics, and, to a more limited extent, arts subjects such as history and languages. Apart from projects which received external funding, most programs have been written privately by schoolteachers. Although some groups have come together in an effort to market and disseminate their software, financial returns are uncertain, and copyright and copying of software is difficult to control. The National Development Programme met similar difficulties. Once funding had ceased, no group of institutions was able to provide enough finance from the circulation and sale of programs to support continued production of software. Thus the National Microelectronics Education Programme, set up by DES, is correct in its priorities of establishing regional information centres and concentrating on coordinated schemes for curriculum developments, and in-service training.

2.2 Evaluation

In spite of the expense of CAL, few evaluation studies have been conducted so many of its claims remain substantially untested. The largest exercise, commissioned in the USA, assessed the PLATO and TICCIT projects (Breland et al, 1974; Alderman 1978). The results, whilst attributing learning benefits to CAL, showed that difficulties in assimilating the technique should not be underestimated. The characteristics of CAL programs (fast calculation and processing, large storage, but rigid language conventions) complement those of the human teacher, so, in contrast to TICCIT, the aim should be to design a teacher-program instructional system (Hartley 1980). However, CAL is most beneficial when it stimulates the individual learner to use and develop his own ideas, whereas the teacher when faced with the practical difficulties of managing a large class has to limit the range of differing learning tasks given to individual students. Of course if the programs are restricted in scope, and only used in a directed way with a whole class, assimilation problems become smaller; but so do the additional learning benefits and the justification for using an expensive teaching machine.

Experience within the National Development Programme showed that to help the teacher resolve this dilemma, programs had to be capable of easy amendment to suit particular circumstances (Hartley et al 1978). For example, simulation programs might need to be run in different ways, to present results in different formats, to give additional feedback and supporting teaching or may require alteration to the underlying model. Most of the current microcomputer based packages are limited in these facilities.

The style of evaluation studies has also been a subject of debate. The TICCIT and PLATO assessments followed quasi-experimental designs (Campbell, D T, and Stanley, J C, 1963) with specified comparisons for testing, a balancing of groups between treatments and an estimation of learning gains and differences through the administration of post-tests. On the other hand the DES National Development Programme adopted a different strategy which placed greater emphasis on subjective reporting. The opinions of participating students, teachers and program developers were taken, the educational milieu were described through their decision-making procedures, and, rather than testing prepared hypotheses, observational methods were used to give a more qualitative case-study type of report (MacDonald 1977, MacDonald et al, 1978). The justification for this approach was to be more informative and more readily illuminate the evolution of CAL within institutions.

On a smaller scale the report of Sledge (1980) followed a similar style and discussed the decisions which faced the Durham Microcomputer Project. He concluded that schools were unable to exploit the full potential of the microcomputer in teaching because the number of machines was limited, the range of available programs was small, they were not always readily transferable, and production of materials within schools was time-consuming and expensive. Sledge argues for the development of flexible software capable of being used in a variety of ways over a larger range of pupil abilities. He believes schools should not disperse their efforts but concentrate resources on achieving modest yet realistic objectives.

The experience of using microcomputers in schools is becoming more prominent in the published proceedings of large conferences (eg. CAL 81 Proceedings with selected papers in Computers in Education 1982 Vol. 6, No. 1; Lewis, R, and Tagg, E D, (eds), IFIP 81 Proceedings). These papers usually describe applications rather than taking stricter evaluation objectives, and, although interesting in the ideas they put forward, are lacking in data and methodology. However an interesting feature initiated in the NDPCAL assessment was the proposal to classify programs in terms of the cognitive processing which their questions and responses required from the learner (Kemmis 1976). The classification included recall, semantic transposition, rule application, hypothesis testing, and model building. Unfortunately, this suggested framework was not exploited in observational studies and so little data was available on how student learning was developed by the various types of CAL programs. Classroom interaction analysis (the SCAN system) is being used by Beeby et al, (1979) in their evaluation of the computer based ITMA materials in mathematics. However, apart from these applications, the value of the technique for studies in CAL remains unexplored.

All these considerations influenced the planning of this research project. For example it was proposed to use three

types of microcomputers; they would have different features (eg. in graphics, and screen character handling), so that comparisons could be made, problems in program transfer noted, and the general reliability of the machines assessed. Sufficient microcomputers would be made available to teachers so that they could vary their modes of instruction from demonstration, to small group work within classes.

A wide range of published programs would be obtained and programming assistance was to be on hand so that teachers could have small amendments made to the material if this were necessary. Help would also be given to those teachers wishing to develop their own programs.

The evaluation was to follow a case-study approach and concentrate on four local schools. As teachers selected and used the CAL programs, data on their decision making would be collected by questionnaire and interview; where appropriate, post-tests would be used to evaluate learning, but interaction analyses would describe types of pupil-teacher activity to allow some description of learning procedures.

It was recognised that commenting on training requirements and methods of extending the interests of teachers in CAL would be significant components of the project. It was desirable to make links within and between schools so that CAL would continue to develop after the research contract had ended.

3. PRELIMINARIES

The grant from SSRC allowed the employment of a research officer, secretarial assistance, and the purchase of some disk-based microcomputers. Together with equipment from the Computer Based Learning Unit at Leeds University, ten microcomputers (four RML 380Z, three Apple II and three North Star Horizon machines) were made available for the research.

The microcomputers differed in their display characteristics. The Apple II machines had medium resolution graphics, but alphanumeric characters appeared crowded on its small capacity display screen. The 380Z's could provide low resolution graphics and present twenty-four lines of forty characters on its terminals whereas the North Stars had the faster processors and used a standard visual display unit. This could give placings for twenty-four lines of eighty characters, but could only show pseudo-graphics through appropriate tab-setting. The 380Z and North Star machines ran under a common CP/M operating system but to transfer programs to and from the Apple II machines, and to take advantage of their differing facilities, required some rewriting of the programs.

Materials were obtained from commercial and other sources including Computers in the Curriculum Project (published by Ed. Arnold), the Warwick Science Simulations, Geographical Association Project (GAPE), and the Computer Based Learning Unit at Leeds. They were modified, where necessary, to run under CP/M on both 380Z and Horizon microcomputers; together with those programs suitable for the Apple II machines, ninety-one programs were assembled and documentation prepared. Most of these packages were of the calculation-simulation type written in BASIC, though some were of a more tutorial nature. [A catalogue of the programs is shown in Appendix I.]

Although the study was to take opinion from a variety of schoolteachers, the research concentrated on the activities of four secondary schools. After discussion with the Local Education Authority, they were chosen to be different in their characteristics and locality: one was an inner-city school, another a suburban comprehensive, the third set in a small town near the city, and the fourth was selective in its pupil intake. Each of the first three schools had approximately one thousand pupils on its school roll, ranging in age from thirteen to eighteen years. The fourth was somewhat smaller and took eleven year old pupils at entry.

In each school there were discussions with the headmaster and with senior and other interested teaching staff. These meetings explained something of the potential of microcomputer assisted teaching, outlined the variety of programs available, and indicated how they might be used in the classroom. The aims of the research were explained, the participation of teachers invited and additional meetings and demonstrations arranged at the schools and/or at the University. Within each school a coordinator was appointed from the teaching staff. His role was crucial; he was to promote CAL generally within school departments and to liaise with the project research officer, who would make regular visits for discussions and to give any assistance required.

4. THE INSPECTION OF CAL PROGRAMS

By September 1980 all the introductory meetings, discussions and demonstration sessions had taken place, and teachers were invited to inspect and comment on the programs and to use them where possible in their classroom teaching. A full set of operating instructions had been prepared to enable any teacher to use the microcomputers and to load and run any of the available ninety-one programs. All were indexed and fully documented, and each school was provided with a copy of these materials together with either one or two microcomputers. Teachers were told that, if they wished, more microcomputers were available, that project staff would discuss and help them in their teaching methods, and would make any necessary

amendments to programs.

In one of the schools the microcomputer was sited in the staffroom for easy inspection of programs; in the other three the machines were housed within departments. Data was gathered through a series of questionnaires. The first invited comment on the documentation accompanying the computer and/or the programs, which also contained advice on points to bear in mind when inspecting the materials. The questionnaires and comments of teachers showed this documentation to be helpful and satisfactory. Certain improvements for cataloguing were suggested - and immediately implemented. The educational documentation and notes on published programs were judged to be generally adequate, but uneven - though of a good standard from one or two particular sources (eg. Computers in the Curriculum). Other suggestions were for information which could not be fully supplied at that time, namely the ages and ability ranges of pupils for which the program was suitable, possible difficulties in using the material, the pupil pre-knowledge it assumed, and suggestions for follow-up work. In short, teachers were requesting a summary and dissemination of classroom experience from those who had used the programs.

A second questionnaire asked for teachers' evaluations and opinions of programs which they had selected for inspection. The questionnaire tried to ascertain those features which made a program interesting, and so requested ratings and comment on the suitability and relevance of the program content to the school curriculum. It asked : how difficult the pupils found the topic in normal teaching; about the probable ease of use of the program, and the ability range for which it was suitable; about features which might make it a valuable aid to understanding and those which were judged counter-productive; and about the flexibility of the program in dealing with different types of pupils, aims and teaching styles. [A copy of the questionnaire is shown in Appendix II.]

Within three or four weeks it became apparent that high initial interest was waning, and that the continued life and development of CAL in the schools would be maintained by a few enthusiastic teachers, or committed departments. This was mainly because inspection had shown teachers that many of the programs were unrelated or had little relevance to their current classroom curricula. Approximately one-hundred teachers (from the four schools and from participants in a three-day Residential Course) inspected the ninety-one programs and seventy-two questionnaires were completed. These selections were spread over twenty-eight different programs (indicated in Appendix I). Most of the teachers maintained that only one or two programs held sufficient interest for them to be considered for use in their classrooms, and a significant proportion of teachers (30%-40%) selected none at all. Apart from three programs in mathematics and one in physics, which were inspected and approved by approximately ten teachers each, almost all the programs of interest attracted

the attention of one, two, or three teachers.

It is difficult to summarise these data which span over sixty teachers commenting and selecting over two dozen programs of various types and subject matters. Nevertheless, the most significant factor influencing teachers' evaluation of programs was its relevance to the syllabus being taught. Programs which did not meet this criterion were given relatively little scrutiny. It was clear that teachers considered few of the current programs to be relevant; even if not outside their teaching syllabus many were concerned with marginal topics, or ones which did not cause difficulty and so could be taught satisfactorily by conventional methods. Some programs elaborated a topic so that to use the CAL materials properly would require extra classroom time which could not be justified. Approximately 75% of teachers noted these points when inspecting programs.

The ease of use of the program by teachers and pupils was also considered to be an important factor. Many respondents thought that more information should be presented on the screen (i.e. help files) rather than in documentation provided with the program. There should be different levels of cueing or instruction depending on the sophistication or experience of the user. Some programs have moved in this direction, but not enough to please the teachers. Approximately 35% of the sample made these or similar comments.

Another factor which influenced teachers' judgements was flexibility in a program's mode of use. Programs which could be presented as demonstrations to the class, as well as being used in small group/individual simulations, were regarded more highly than those which could not. This flexibility was considered to be particularly important when the number of available microcomputers is limited. Approximately 30% of the teachers noted this point.

The type of display which a program can employ is dependent on the facilities of the computer terminal; some programs betrayed their printing-terminal origins and only gave a numerical output. A significant proportion (35%) of teachers considered this to be unsatisfactory, maintaining that any program producing numbers must also be capable of giving some form of graphical display. The RML 380Z microcomputers had low resolution graphics; the North Star Horizon machines had to achieve this by Tab-plotting - though not as good, it was generally considered adequate.

The accuracy of some of the models used in the simulation programs was questioned, particularly when the supporting documentation gave few details of its derivation. Approximately 15% of the teachers were concerned that some generalisations made after using a program could cause pupils to become confused, unless the teacher was careful in his approach and in follow-up instruction.

Another point of concern was the way key points were presented by some of the programs. This judgement is partly dependent upon the style and function of the program, i.e. if the contours of the material are to be shaped by the program itself or by the teacher in his supporting instruction. Some 15% of the teachers made this comment when inspecting the programs.

Naturally, the intended pupil-ability range of a program was considered an important feature. Some aspects which attracted criticism included cluttered presentation, a lack of clarity in feedback, and inadequate explanation of what the program was undertaking or trying to represent or achieve. However, all of the twenty-eight programs chosen and inspected in detail were judged to have merit. Although they cover different subject areas, it is useful to group them and show the average ratings they attracted from the sample of teachers. These ratings are taken from length markings on a bi-polar ten-centimetre line, and arranged in Table 1 below on an increasing scale so that the more desirable axis point is ten.

CRITERION	AVERAGE RATING
Suitability	6.2
Relevance	6.7
Topic Facility	5.4
Programs Ease of Use	7.6
Understanding Program Commands	6.9
Adequacy of Documentation	6.4
Flexibility of Use	75% noted Inflexible

TABLE 1
A summary of teachers' ratings of twenty-eight programs

When asked to appraise CAL materials teachers are naturally critical though constructive. The comments summarised above should not be allowed to disguise the favourable ratings attributed to the twenty-eight programs.

5. THE USE OF CAL PROGRAMS IN TEACHING

During the first two terms of the 1980-81 academic year, staff from the four schools were repeatedly encouraged to make use of programs in their classroom teaching. It was emphasized that the research team would make amendments to programs if this were necessary, and/or help any teachers to design and implement their own CAL materials. They were also told that one microcomputer would be provided for each school, but that at a later time, clusters of machines could be made available. Thus initially, teachers were required to face the situation, common in many schools, of having access to only one microcomputer, but they were offered the prospect of greater resources when they were more familiar with the techniques.

After the selection of CAL programs but prior to their use in actual lessons, a questionnaire-based interview was arranged to discuss objectives, particular features of the learning program and organisational matters. The classroom interactions were to be observed, and an interview/questionnaire was designed to collect retrospective opinion on points of success and difficulty. Teachers could use the programs privately if they wished, but in practice they were all amenable to this collection of data by the research team.

5.1 The selection of programs

Overall it must be recorded that the take-up of programs was relatively small. Fifteen of the ninety-one programs were used, some by more than one teacher, and a total of twenty-two lessons were observed. Of the fifteen programs only ten were chosen from the published lists. The others were designed by teachers to suit their own needs. The program utilisation was not uniformly distributed; two schools (in which sixteen observational studies were carried out) used the CAL materials much more than the others. [The chosen programs are shown in Appendix I.] Although teachers from a variety of departments were encouraged to use the microcomputer (the utilisation across subject areas is shown in Table 2) there was a distinct bias towards the school coordinator's own department.

Subject Area	Hist.	Econ.	Geog.	Biol.	Chem.	Phys.	Maths.	Total
No.of programs chosen	1	0	2	6	1	1	4	15
No. of Lessons observed	2	0	2	9	1	2	6	22

TABLE 2
The choice and utilisation of programs across subject areas

Table 3 shows the average ratings which teachers gave to these selected programs. Not unexpectedly a comparison with Table 1 indicates that they are even more desirable on grounds of suitability and relevance. In discussion these value judgements were re-emphasized.

CRITERION	AVERAGE RATING
Suitability	7.4
Relevance	7.7
Topic Facility	5.7
Programs Ease of Use	7.5
Understanding Program Commands	6.8
Adequacy of Documentation	6.3
Flexibility of Use	67% noted Inflexible

TABLE 3
Teachers' ratings for programs selected for use in teaching

Again, the most frequent comments on rejected programs implied that the content was not directly relevant to teaching syllabi, or was concerned with marginal topics, or small in conception so that the time and effort needed to exploit the programs could not be justified, or dealt with subjects which created no significant teaching problems nor conceptual difficulties for the pupils.

Teachers completed a short questionnaire [Appendix II, Questionnaire Three] on each of the programs they selected. It asked why they had decided to use those particular CAL packages, what contributions they could make to classroom learning and what would be required of pupils and teachers to achieve these objectives. Since the take-up of packages was small, the results are based on fifteen responses only, and should be cautiously interpreted.

The first question asked what particular features of the program or its content were influential in its selection. Nine replies pointed to the relevance of content to the classroom syllabus, two quoted the advantages of the CAL program itself (eg simulation for providing illustration not possible by other means) three teachers noted the display/representation advantages of the microcomputers, and one mentioned the flexibility of the program for different ways of teaching.

When asked about particular difficulties in teaching the subject matter, five replies were concerned with difficulties of providing data/material for illustration, five complained of routine work (eg numerous small calculations) interrupting the flow of teaching/learning activities, two teachers noted cognitive difficulties in understanding the concepts and three considered there were no particular problems. Clearly microcomputer based programs should be capable of overcoming the first two types of difficulties. This was confirmed by the replies to a third question which asked about the particular contributions the CAL material was expected to make. Five responses underlined the advantages of simulation, four the particular consolidation and practice which could be provided; three pointed to pupil involvement the program required and three to the novelty value of the microcomputer to the lesson.

Some preferred modes of using the program were distinguished. Three teachers proposed a demonstration in which the class would participate as a whole, six suggested a short teacher demonstration followed by individual pupil use, and six teachers proposed group work after a teacher introduction. [In these replies teachers were anticipating that a small number of microcomputers would be made available]. Eight teachers also considered that the main purpose of the materials was to supplement and develop the classroom instruction, and a further five would use the program itself as the basis of the lesson. The remaining two replies saw the prime role of the CAL package to be reinforcement of material already covered by convential methods.

Most teachers, ten of fifteen, considered that resource materials, student worksheets and/or handouts would be needed to make most use of the programs, and the times given to lesson preparation reflected this judgement. Those developing supplementary materials thought three hours per lesson would be necessary, but others considered fifteen minutes (on average) to be adequate.

In summary, relevance and easy direct introduction of CAL materials into existing instructional procedures are the main considerations when teachers are assessing programs for use in lessons. Also simulation type programs are valued for the illustrations, activity and novelty they can provide, and the opportunities they give for developing small group or individual work.

5.2 Planning the use of programs

Before a program was used in the classroom, and when a particular lesson was being planned, teachers were asked to have discussions with the research officer and complete a short questionnaire. The principal aims of the meeting were to give any necessary help in planning and preparing materials, and to ascertain the actual objectives and teaching methods which would be used. It was hoped to relate these decisions to the conduct of the lesson (to be described through an interaction classification scheme) and to the teachers own evaluations of its success. In the event pre-interviews/questionnaires were completed on nineteen occasions, and although it is difficult to briefly summarise the data they provided (which applied to different programs, subject areas, classes and ages of pupils) some general comments can be made.

A copy of the questionnaire (Four) is given in Appendix II. The first questions asked about educational aims. Most of the teachers referred to objectives which can be broadly classed as comprehension of content or the ability to carry out standard techniques. Ten of the nineteen responses did not go beyond this, but three mentioned the establishing of relationships (eg understanding the relative importance and effects of the variables which underpin the simulation model) two stated the importance of applying the model or its underlying principles to new situations, (eg the testing out of what - if hypotheses) and three teachers mentioned the aim of developing pupils judgement and powers of explanation. Of course these aims reflect not only teachers predispositions, but the ages and abilities of their pupils, and the characteristics of the CAL program and its intended administration.

A second question dealt with expected teaching difficulties relating to particular class lessons. It drew a variety of replies. Two teachers considered there would be none, six that pupils lack of interest or poor pre-knowledge might cause

problems, and four that limited access to the microcomputer(s) and/or that running the programs might prove awkward. A further four teachers felt that the program might be used by the pupils for data gathering without understanding or interpretation, and three teachers considered that the concepts being taught in the lesson were inherently difficult.

The main methods for overcoming these problems were to ensure that pupils were adequately prepared through pre-teaching, that demonstrations were given with the microcomputer, and that the class was well administered and active in learning. The latter was thought to require prepared worksheets and/or resource materials. It was felt that the novelty of the microcomputer, the additional program and teacher feedback which could be given, and the qualitative features of the CAL illustrations would compel pupil interest and overcome some of the conceptual difficulties they might otherwise have experienced.

Accordingly the teaching organisation tried to introduce group or individual work especially when more microcomputers (eg three to a class) were made available. Thus, in the nineteen lessons there were five class demonstrations, three class introductions followed by individual or paired working, and eleven group based lessons.

The last two items of the questionnaire showed that all but one teacher judged preliminary training and preparatory subject matter teaching could be done within the actual lessons which used the microcomputer. For the lessons, five teachers prepared pupil worksheets, two printed some test questions, and three provided and used extra resource materials; nine considered that none of these was necessary.

5.3 Describing the classroom use of CAL materials

A scheme was proposed to describe the nature and quantity of teacher-pupil-program interactions in terms which relate to possible effects on learning. A lesson was considered to be a series of events or interactions of a certain **type** (educational,administrative or other) within a general teaching **mode** (Exposition/dialogue, Question/Answer, or Activity). Each interaction has a **source** and an **address** point; the source is regarded as the instigator of the interaction and the address the receiver. These participants may be the teacher, the whole class, a pupil group, an individual pupil or a computer program or resource sheet, and the interaction (coded under these descriptive headings) is placed under the participant who takes the initiative and acts as the source.

The **educational** interactions were further related to the types of learning they were supposedly encouraging. A six-fold classification system was proposed which made reference to the earlier schemes of Kemmis (1978). It was developed after

studying the types of CAL programs available and discussing with teachers the ways they might be used. A first category was labelled **attention**; it requires a largely unchanged response from the pupil and may be obtained in answer to a question from the computer screen, or the blackboard, or a resource sheet or from information which had just been stated. A second category, **comprehension**, demands some semantic rephrasing or translation of given information. The next three categories were concerned with the elaboration of pupils knowledge by building **relationships** between concepts, by **applying** these rules or hypotheses in other contexts, and by being aware of the limits of their **generalisation**. A final category labelled **construction/evaluation** lays stress on semantic organisation, where the pupil has to develop or construct a line of argument or explanation. [The total analysis scheme is summarised in Appendix III.] As a brief example, consider how the categories might apply to the FARM simulation program where the user has to decide on the acreage of planted crops. The farm can be located in three parts of the country, weather and crop yields are determined by the computer probability model, and feedback is given in the form of cash profits. Questions on parameter values or data shown on the screen would be labelled ATTENTION, those about total yield or weather differences, COMPREHENSION, and questions/activities on the relative importance of parameters (eg weather influences on various crops) gained by running the program under different parameter settings would be noted as RELATIONSHIPS. Moving the farm to a new part of the country (a new context) could give APPLICATION, appreciating the limitations of the model (eg the conditions under which it breaks down) would be labelled GENERALISATION and discussing the construction/development of a new, or improved model would be an example of CONSTRUCTION/EVALUATION. Of course simply having a computer program (for example) run repeated simulations does not guarantee RELATIONSHIP learning - that arises out of the ways the data is actually used by the learner.

In similar way the analysis was applied to convential teaching/learning interactions. Pilot studies showed the scheme to be manageable after some practice, but the judgements are necessarily subjective and only in a few lessons could the research team have two independent observers present. Further, when the class was divided into several working groups, only a sample of events could be categorised.

The scheme allowed an observer to note time (at approximately three minute intervals). The interest level of the class was periodically rated on a five point scale, and a comments column permitted the content of the exposition, questions or activities to be summarised. [An outline of the interaction scheme is shown in Appendix III.]

For each of the twenty-two observed lessons, in addition to the questionnaire/interviews with teachers and the interaction

analysis data, questionnaires were given to the pupils. In general these asked: if the computer made the lesson more interesting and in what ways; what had been learnt from the computer about the topic area; and in what ways (if any) the computer was better than a normal lesson.

5.4 Some Comments on the use of programs

During the Autumn Term of 1980 and the Spring Term of 1981 twenty two lessons which used CAL materials were observed. At the conclusion of each period of instruction questionnaire/interviews were arranged (where possible) with the teachers in order to record their impressions and personal evaluations. [A copy of the questionnaire (Five) is shown in Appendix II.]

In the event nineteen interviews were given and a first question asked if lesson objectives had been achieved. Only one teacher admitted to failure, three claimed modest success, seven stated that expected outcomes had been largely achieved and eight judged that the lessons had been very successful. The data which led them to make these conclusions was largely based on subjective impressions of class reactions, through the interest pupils showed in discussion and level of participation. Seven teachers included test and homework results in their judgements, and five primarily based their evaluations on the standard of classwork and the quality of pupils answers to class questions.

The next questions were directed at the CAL programs themselves. Did they meet expectations? Twelve teachers answered 'Yes' without reservation, four considered they were largely satisfied, three partially so, and one was disappointed. Again the principal criterion was pupil motivation and interest. Fifteen gave this as their main impression, but three of the four remaining teachers were more complimentary of the pupil-thought and level of understanding required by the programs. Responses on features which contributed to this effectiveness were more varied. Seven teachers noted data display and quick calculation speed, five the program structure, three the individualisation given to the instruction and three again underlined the pupil involvement generated by the materials. The one teacher who judged the lesson unsuccessful blamed the program for causing pupils to be confused, largely through the way information was presented by the simulation package. Under other difficulties mentioned, four teaching staff referred to class/group administration with limited numbers of microcomputers, and some half dozen mentioned program limitations in range of variables allowed by the simulation models and/or crowded presentations of output data.

All these teachers, with the one exception, would use the

programs again as part of their classroom instruction. Of course there were suggestions about ways in which the packages could be improved. These largely concerned the presentation and display of data and feedback, but two comments proposed refinements to the simulation model and ways of making its teaching application more flexible. When asked in what ways the instruction might be different if the experience were repeated, no one proposed making any significant change in teaching content or strategy. Five would make no changes in class administration, but the remainder wished to improve and increase the activity of the pupil groups. Five proposed greater preparation time and increased microcomputer access for pupils, and eight teachers would have a tighter administration based on resource/work sheets, both for those using the microcomputer and those engaged in other classroom activities. From these discussions and the observations of the teaching sessions it was clear that - at least initially - there was some reluctance to make any significant changes to the way a teaching subject was approached in order to exploit the new technology.

The teaching methods used in the classroom were strongly influenced by the class size and the number of microcomputers available. In general, teachers were keen to maximise the activity at the terminal and to give hands-on experience to as many pupils as possible. With only one microcomputer for a class, opportunities were limited (in fact one of the four schools was extremely reluctant to take up this method of administrating CAL). Usually the accepted mode was for teacher-directed class discussion, with the teacher or nominated pupils typing responses and the rest note-taking. Even in these circumstances teachers were anxious to allow time for group or individual work with the microcomputer during the lesson when general class activities were taking place, or at lunch-time or after lessons finished for the day. Having three microcomputers allowed greater flexibility. In addition to demonstrations, the class could be divided in two with one half being taught or completing set work, while the other used the microcomputers in groups. Alternatively, pupil groups used the microcomputers on a cafeteria system.

Whichever mode of use was followed, it brought administrative complexities which, on occasions, were underestimated by teachers. With one microcomputer, enabling all pupils to read the display can cause problems even when a large TV monitor was used. In some schools such monitors were not always available; even if they were, it required moving equipment and microcomputers to the required room, setting them up and loading the programs in time for a prompt start to the lesson. On one or two occasions the teacher found himself making these preparations at the beginning of the lesson or having to type 'blind' because he had positioned the equipment for better display to the class. Further,many of the programs had not been designed with class demonstration in mind so the screen appeared crowded with the data and feedback hard to take in -

hence the requests for different forms of graphical display as an alternative to numerical tables.

With current designs of CAL materials, three microcomputers were as much as the teacher could manage within the class. Pupil questions and discussions generated by pupil groups using the programs were enough to keep the teacher busy, and the rest of the class working off-line had to be serviced also. Such an exercise needed careful management and scheduling, and there were occasions when substantial queues of pupils built up around the microcomputers, or when pupils were unable to understand the data or to progress with their use of the machine until the teacher had time to give help. These difficulties can be ameliorated by pre-teaching, by the use of worksheets and by improving the designs of the CAL programs. The teachers commented on increasing the flexibility of the simulation packages so they can be run as class demonstrations or as group activities with more help/teaching being available within the programs themselves. The aim was to make them more responsive to the varying experience and knowledge of pupil groups. It was also noted that, on occasions, teachers tended to underestimate the prior training needed to use the microcomputer and its programs. Certainly the computer procedures are simple enough and familiarity is achieved fairly quickly. However program commands and response conventions are often idiosyncratic to a particular package, and sufficient prompting to overcome confusion is not always available.

As well as pupil/machine ratio and program designs guiding the conduct of the lessons, a significant influence was the differing educational functions assigned to the CAL packages. The interaction analysis showed some of these differences. Most of the programs were of the simulation/calculation type and were given three functions. First they could be used as an introduction or preparation for the teaching by providing data which would be explained in the lesson. Second they could be used as illustration or consolidation of teaching which had been given in class eg for the FARM program, the principles relating weather to location in the UK and to crop yield could have been discussed and the program would then be used to test/verify these principles. Third the program could be used in a more open-ended fashion to to find out about, or 'discover' the properties of the underlying model. These tasks might be undertaken with the class as a whole (guided by the teacher), or with smaller groups of pupils (guided by the teacher and/or by worksheets). The groups could work in cooperation (i.e. each group contributes data to a common data pool), or independently, or in competition (eg. in the FARM program, profits can be maximised by obtaining good crop yields, so the finances of each working group could be compared). In using these simulation programs, three tasks have to be undertaken; namely, supplying parameter values, noting what data are given as output, and interpreting these results.

Overall, the analysis scheme showed that teachers did not break new ground, but used the programs to consolidate principles they had covered before. The teachers, or their questions/worksheets were clearly the initiators, and for group work it was likely that pupils would have seen a demonstration or a trial run before they obtained their own readings; generally, the programs provided data to check on relationships which were already in mind. If this pre-teaching were too direct, then the CAL exercise became one of **comprehension**, and the interaction analysis scheme indicated that this was a prominent category. Other lessons used this with additional questions to bring out and justify the **relations** between parameters and included some limited **application**. In no case was there significant discussion of the limitations of the model through comparison to real-life situations or argument about its reconstruction. Teachers tended to decide if the model were useful and applicable and leave it at that; where there were serious reservations about some of the assumptions (in Economics, for instance), these programs were not taken up.

Very occasionally, pupil groups were presented with a more open-ended task, perhaps one which required them to use the program "to find out about ..... ". These sessions were not too successful. To carry out a discovery task not only requires a sufficiently structured body of knowledge to guide hypothesis testing, but experience of how to sequence such hypotheses in a systematic fashion. For example, in the Farm program, the variables are, weather, crop-acreage/yield, and farm location. It is a sensible procedure to keep constant one of the latter, farm location say, and study the interaction between the others (weather and crop-acreage/yield) before systematically applying the same decisions in different locations. Without such order, the relationships are likely to remain hidden. Bork and Robson (1972) encountered similar difficulties when using wave simulation programs with Physics students. Thus, the teacher is placed in a difficult situation. If he is conservative in his decisions and does not exploit the potential of the programs, learning benefits may be reduced: if he tries to develop more open-ended tasks which give pupils more responsibilities for developing their own ideas, they can become over-faced and confused. Perhaps these more demanding objectives should only be attempted with older and more able pupils; certainly, they are likely to require more help/guidance within the program together with the development of project-type resource materials. Experience suggests that the assimilation of these teaching techniques will be a relatively slow process.

The interest ratings noted on the interaction coding sheet were high and indicated that, in general, the programs drew a good response from pupils in whole-class or in smaller working groups. This opinion was strongly apparent in the replies to the pupil questionnaires.

It was the usual practice for groups to work independently, producing and using their own data rather than contributing to a common data pool. On a number of occasions an element of competition (eg. comparing the group incomes when using the Farm program) was put to good effect. However, it was noticed that when four or five pupils were grouped round a microcomputer, the stronger personalities could dominate the activity and influence, even override, the decisions of those who were typing the responses. Teachers were aware of these difficulties; on occasions they engineered a better group balance and/or required each pupil to note down his data and his own conclusions.

Being able to observe twenty-two lessons within a variety of schools and subject areas, with different teachers and equipment, provided several interesting comparisons. On some occasions the same teacher used different administrations (demonstration versus group work) of the same program with equivalent classes. The teachers' own preferences and evaluations were for the group situation, even when this was less administratively successful than the class demonstration. Again, teachers in different schools used the same program with equivalent classes, and the administration and the outcomes could be very different. The influence of pupil's ability level and range on the modes of use of the program was also in evidence, particularly as some schools followed a streaming-, and some a mixed ability-policy, for making up their classes. In general, the programs were well-chosen; only in one instance did the material seem inappropriate for the ability level and range of the class.

Finally, although schools differed in their take-up of the programs (in the terms outlined previously), they were similar in their comments on the programs and in their methods and evaluations of using the CAL materials. The microcomputers themselves showed adequate reliability - and they were allowed for some school use outside CAL. There were only two breakdowns, both with 380Z machines.

6. A COMPARISON STUDY OF CAL IN MATHEMATICS

In many of the CAL applications it was neither possible nor appropriate to undertake comparative learning experiments against convential methods. However, during the Summer Term of 1980, members of the Mathematics Department of one of the schools suggested a more extensive application of CAL based on a laboratory of six microcomputers. The teachers proposed this cluster of machines to allow an entire class to work concurrently in groups. The subject area, the representation of data through equations and straight-line graphs, caused some teaching problems, particularly with the lower-ability pupils, and CAL materials could have several advantages. For example,

the graphical displays at the terminal might provide clearer illustrations of systematic differences between equations in terms of gradients and intercepts; the programs might engage and keep the interest of pupils better than conventional methods, and the materials could permit more intensive practice. Accordingly a comparative experiment was set up in order to test these claims.

6.1 The materials and conduct of the experiment

The classes chosen contained fourteen-year old pupils, and were of mixed ability and sex. Fourteen classes of approximately twenty-five children were used in the experiment; eight classes were given instruction using CAL programs and six followed conventional methods, though the latter groups had the opportunity of using the microcomputers at the conclusion of the experiment. Eight teachers participated in the study which extended over a period of three to four weeks.

In the opinion of the school mathematics staff, no suitable CAL programs in the subject area were available. The nearest was the GRAPH package written by the Computer Based Learning Unit at Leeds University, but this was considered too complex for their purposes. Hence the teachers proposed their own modified specification for a set of programs which would suit their preferred methods of instruction. The first program produced an equation and a pair of axes on which pupils plotted points by specifying their coordinates. After a sequence of six had been located to represent the given equation, the user was allowed to make changes. The correct equation-line was then plotted by the program and showed clearly any errors which the pupil had made in his point specification. The equations became progressively harder by introducing negative and decimal numbers for gradient (m) and intercept (c).

A second package asked pupils to specify values for m and c after which the straight line y=mx+c was plotted on the screen. This could be done for a variety of related equations in order to compare differences in gradient and intercept. The exercise required each pupil to express in words the relationship between the m and c values and the graphical features of the equation set. Both programs were written in BASIC for use on Apple II, North Star Horizon and 380Z microcomputers.

The treatment and control groups received the same amount of teaching - six lessons. For those classes using CAL materials, four of the six periods required the microcomputer. A laboratory of six machines (two Apple II, two North Star and two 380Z) was set up in the school. Instruction in using the programs was given in the lesson time by the eight teachers taking part in the study. All groups received the same content/teaching sequence, used similar worksheets and completed the same post-tests and questionnaires. The Project

Officer interviewed teachers when they were planning the organisation of the lessons, and collected data using the lesson observation/analysis scheme. A group discussion involving all the participating teachers and members of the research team took place when the experimental work was completed.

The post-test results showed benefits favouring the CAL groups,but these differences failed to meet the established levels of statistical significance. The mean scores and standard deviation of the treatment groups were 17.9 and 8.8 respectively (n=182) and the maximum obtainable score on the post-test was 25. The conventionally-taught groups (n=132) obtained a mean score of 16.7 (standard deviation 7.7) on the same test-questions. The lack of a clear-cut learning advantage to the classes using programs was not altogether unexpected. The two packages were designed to follow closely the established syllabus in both content and style of teaching. Indeed, the same example sheets were used by all the fourteen classes so that differences had to come about, not through differing cognitive demands made on the groups (confirmed by the observation schedules), but through the interest and feedback provided by the program, and through additional opportunities for the teacher to instruct small groups of pupils.

The two programs performed satisfactorily but the effectiveness of the second was dependent on pupils systematically varying m and c so that the resulting straight-line graphs could be more readily inter-related. From pupils' working, it seemed that the effect of m-values became appreciated but not those of c.

Questionnaires were completed by teachers immediately after the study. They indicated that the staff considered the programs to have motivated their pupils, particularly the less able in spite of the difficulties some of these pupils experienced in understanding the subject matter and in using the programs. The observation schedules also confirmed a very satisfactory interest level in CAL classes (on average approximately 3.5 on a 5 point scale). The teachers' questionnaire responses showed that they considered the objectives of the programs to have been achieved, though some of the staff had reservations about the second gradient/intercept program. They questioned its effectiveness with the less-able pupils in relating the algebraic and graphical representations.

The value of group work and the help the programs gave in promoting this type of instruction was emphasized by the teaching staff. The materials provided a working context with teachers able to discuss the graphical illustrations shown on the VDU screens and the performances and decision making of pupil groups. The composition of working groups was decided by the teachers themselves; some followed friendship patterns, others grouped them on abilities. Observation suggested the former method could have some disadvantages as the dominant

friends could take over most of the activity, unless checked by the teacher. The other ability groups seemed to function more democratically.

Overall, the exercise had some success. It had brought departmental staff together in a cooperative teaching exercise; the CAL materials had drawn a good response from the pupils and through its group work had allowed the teachers more mobility in the classroom. It is worth noting that since this experiment was completed the department has repeated the technique in another teaching area.

7. TRAINING AND DISSEMINATION

The SSRC evaluation project, and the materials and programs it was using stimulated local interest. As a consequence a three-day residential course was organised at a regional training centre in November 1980, and fifty schoolteachers and advisers from five local authorities attended. The course included an introduction to microcomputing (hardware components, peripheral and terminal equipment, choosing a microcomputer, and software support); educational functions of the computer; types of CAL program designs; and inspecting, using and evaluating CAL materials. Workshop sessions were based on the questionnaires and programs which were being used in the SSRC evaluation study, and discussions and collected data produced opinions and conclusions very similar to those encountered in the four schools. Current programs were criticised on relevance, and flexibility of use, and there was concern that teachers should be substantially involved in any curriculum developments. The course was very successful, produced a wider range of teacher contacts and will be repeated within the next few months. It also became clear from the research that any training course dealing with the assimilation of CAL should contain actual case-studies taken from classroom experience; examining and discussing programs, though useful, is not in itself sufficient.

During the last eighteen months the University of Leeds, through the Computer Based Learning Unit and the School of Education has established an Advanced Diploma in Computers in Education. The SSRC project and the experience it provided was useful in shaping this course, which was primarily designed for teachers in Secondary Education. The Diploma is for part-time study and is of two years' duration. The first (twenty-four) students were admitted in October 1981, but such was the demand that an equivalent one-year full-time course is a likely development. The research has also stimulated an increasing number of studies within the M.A., M.Ed. and M.Phil. degree schemes. With the approval and support of local education authorities, a Teaching Associate Scheme is now coming into operation at the University, in which seconded teachers will be

working with the Computer Based Learning Unit on the development and evaluation of CAL curriculum materials in schools.

The research work has also been disseminated through conferences and through publications. The biennial conference, CAL 81, was held at the University of Leeds in April 1981, and was attended by four hundred delegates from the UK, Europe and the United States. There were several papers on evaluation, and the application of microcomputers to school education. Two presentations were given by the research team. Consequently a paper will be published shortly in a special issue (on Microcomputers in Education) of the International Journal of Man-Machine Studies.

A wider audience has been reached through articles commissioned and published by Educational Computing (Hartley 1981) and by the Times Higher Educational Supplement (May 1981): the SSRC Annual Report (1981) was also able to feature this research.

Since the start of the SSRC Project, major initiatives have been taken by the Government through its Microelectronics Education Programme (MEP) for schools. With the aid of Department of Industry funding, almost all secondary schools are likely to have at least one microcomputer, and one of their major uses will be Computer Assisted Learning. Features of the MEP Programme include the establishment of Regional Information Centres, and the promotion of in-service training and curriculum development schemes in order to produce and assimilate appropriate microcomputer-based materials. The six local authorities forming the West and North Yorkshire Region have become part of the National MEP Programme; the Computer Based Unit at Leeds University has been proposed by the Regional Steering Committee as its designated centre for CAL.

8. CONCLUDING COMMENTS

This research examined current Microcomputer Based Learning programs, and studied their use within the classroom. In the event, the take-up of programs was relatively small since teachers were particularly concerned about the direct relevance of the materials to their school syllabus, the inflexibility of the programs in suiting different modes of use, and presentation defects in feedback and data at the terminal. They were also aware of the limited range and type of present materials - almost all are of the simulation/calculation variety, concentrating in the Sciences, Mathematics, Economics, and Geography. It was recognised that the production of suitable CAL material would be difficult, time-consuming and expensive, and that teacher groups would need appropriate training, and some relief from their normal duties if they were to take a proper part in such curriculum developments.

The Microelectronics Education Programme, through its regional organisations will help with initial training, some curriculum developments and the dissemination of programs. But within any one region available funds are relatively modest. Therefore, it is essential that CAL training programs be informed by research, and that studies are initiated to stimulate and guide curriculum developments. Such research may experiment with educational data bases, problem-solving packages, learning laboratories (eg. subsets of LOGO) learner control systems, and adaptive tutoring with remedial groups. These types of materials not only make their own contribution to learning but complement the simulation-type programs: at present however, they are not prominent in school-based CAL. Research could also examine how the designs of these programs influence their learning function and efficacy. In the study reported here, discussions with teachers ranged over topics such as representation of concepts, their presentation (eg. graphics) at the terminal, types of feedback, activities required of the learner (to which the interaction-analysis scheme related), the place of learner initiative, and the organisation and development of knowledge structures by students.

Flexibility in program design was another recurrent theme. Teachers wanted programs to suit their own circumstances, to cope with differing styles of use and ranges of pupil ability. Of course, in many tutorial systems, progress is governed entirely by program performance; in contrast, simulation exercises leave the pupil free to use the program how he will, and no records are kept for the next occasion. It seems important to devise systems which aid the teacher by allowing control and initiative to move between program and pupil (or pupil group) and for the programs to advise as well as direct or leave alone. To some extent these requirements might appear complex and hence run counter to the economic production of CAL material, but this need not be so. The teacher is well able to produce the teaching content, activities/questions and feedback. If, for his type of application, research could suggest and specify a teaching style, (i.e. the presentation rules for material on the display screen, and the decision rules/control structures and learner initiatives which operate), this skeleton can be pre-programmed and the resulting high level command language used by the teacher to develop his own material. [Examples of such teaching systems have been developed at Leeds (Hartley 1980) and are now becoming available on microcomputers.] For example, in problem-solving materials, learners can seek what help, explanations and evaluation they need from the programs. A command language allows them to work through the problem in total, in stages or in smaller steps. The material is pre-stored but commands allow users to question goals (WHY DO?) and strategy (HOW DO?), and to explore their errors (WHY WRONG?). Other commands give access to facts files, allow summaries of progress and permit some backtracking. It is the teacher who sets out the problem,

the answers to the queries, and the supporting information. This material is inserted into the program skeleton and the computer produces the run-time version of the program.

Clearly small programs will continue to be written (for example in BASIC) by teachers for their own purposes, but if research could make available a more general range of supporting software (such as the teaching systems outlined above) which is less dependent for its use on detailed programming knowledge, then curriculum developments would greatly increase.

When teachers came to use and evaluate programs in the classroom, a prime concern was the type of activity they stimulated in pupils. Although evidence of learning gains was important, the immediate judgement was given to the interest the program aroused, the questions it drew from the pupil (or pupil groups), and the opportunities it provided for development and supporting instruction. Thus when planning lessons, teachers tried to allow hands-on experience. With one microcomputer this was barely possible, even if the programs were made available during lunch-breaks or after school. With three machines, group work was feasible, but the organisation was not easy and the teacher had to show considerable judgement. If he were too directive, or followed conventional teaching methods too closely, the program could not stimulate the pupils to try out and develop their own ideas; it merely provided data. On the other hand, finding the properties of the relational model was likely to prove too difficult for the less well-prepared or the less able pupils. Thus programs need to adapt and give support to a wider range of objectives. Such flexibility is a function of the knowledge the program holds of the subject matter, of students capabilities and of decision rules for teaching. As more research on intelligent teaching systems becomes available (for example, **International Journal of Man-Machine Studies**, Volume 11, 1, 1979), so CAL materials should attempt to become more knowledgeable.

This research also suggests that, to aid assimilation of CAL materials, training courses for teachers should include discussion of case-studies taken from the classroom. Program designs should also take more account of the actual circumstances in which they may be used. Further it is crucial that evaluative research is undertaken as curriculum materials are designed. Such research may not be easy to effect and will need to give careful thought to rationale and technique, but it is necessary to help innovation, and to provide direction for teachers and those engaged in curriculum developments.

CAL has considerable potential for school education and the continuing improvement in computing technology, peripheral equipment and software will add to its promise. This research has pointed to the interest of staff and pupils but the interest will fade if not supported by a considerable and coordinated effort in curriculum development and software support. These are the aims of the Microelectronics Education

Programme, but learning benefits will be hard to achieve and such activity will need to look to research both for guidance and for stimulation if it is to break new ground and become successful.

ACKNOWLEDGEMENTS

The authors thank the Social Science Research Council for supporting the research; the Local Education Authority; and the headmasters, coordinators, teaching staff, and pupils of the schools who were willing and conscientious participants in the study and who provided the data which form the basis of this report.

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APPENDIX I

A LIST OF AVAILABLE PROGRAMS

APPENDIX I : A LIST OF AVAILABLE PROGRAMS

PROGRAM	SOURCE	TYPE	SUBJECT	OF INTEREST	USED IN TEACHING
ACDBSE	Central Program Exchange	SIMULATION	CHEMISTRY		
AGCOM1	Computers in the Curriculum	SIMULATION	ECONOMICS		
AGCOM2	Computers in the Curriculum	SIMULATION	ECONOMICS		
ALPHA	Warwick Science Simulations	SIMULATION	PHYSICS		
ALPHA2	Improved version of ALPHA	SIMULATION	PHYSICS		
AMOON	Warwick Science Simulations	CALCULATION	PHYSICS		
ANIMAL	AUCBE, Hatfield	GAME	BIOLOGY	Yes	
AREAS	Computer Based Learning Unit	CALCULATION	MATHS	Yes	
AUTOSUM	Computer Based Learning Unit	PRACTICE	ARITHMETIC		
BINOMIAL	School	CALCULATION	MATHS	Yes	Yes
BISECT	Computer Based Learning Unit	CALCULATION	MATHS		
BSTATS	Computers in the Curriculum	CALCULATION	BIOLOGY		
CAPDIS	Computers in the Curriculum	CALCULATION	PHYSICS		
CHAGGA	GAPE	SIMULATION	GEOGRAPHY		
CHARGE	ITMA Project	SIMULATION	PHYSICS	Yes	Yes
CMPETE	Chelsea Science Simulations	SIMULATION	BIOLOGY		
COBWEB	Computers in the Curriculum	SIMULATION	ECONOMICS		
CONTCT	Computers in the Curriculum	SIMULATION	CHEMISTRY		
CORR	GAPE	CALCULATION	GEOGRAPHY		
COUNTR	Computers in the Curriculum	SIMULATION	BIOLOGY	Yes	Yes
CREDIT	Computers in the Curriculum	GAME	ECONOMICS		
DECOMP	Computers in the Curriculum	CALCULATION	CHEMISTRY		
DEMOG1	Computers in the Curriculum	SIMULATION	GEOGRAPHY	Yes	Yes
DEMOG2	Computers in the Curriculum	SIMULATION	GEOGRAPHY		
DRIFT	Warwick Science Simulations	SIMULATION	BIOLOGY		

PROGRAM	SOURCE	TYPE	SUBJECT	OF INTEREST	USED
ECELLS	Computers in the Curriculum	SIMULATION	CHEMISTRY		
ELAST	Computers in the Curriculum	GAME	ECONOMICS		
ELEMNT	Computers in the Curriculum	GAME	CHEMISTRY	Yes	Yes
ENERGY	Computers in the Curriculum	CALCULATION	BIOLOGY	Yes	
EQUILA	Computers in the Curriculum	SIMULATION	CHEMISTRY		
EQUILB	Computers in the Curriculum	SIMULATION	CHEMISTRY		
ESCAPE	Computers in the Curriculum	CALCULATION	PHYSICS		
EVOLUT	Chelsea Science Simulations	SIMULATION	BIOLOGY	Yes	Yes
EXPSTP	Warwick Science Simulations	CALCULATION	MATHS	Yes	
FACTORL	Computer Based Learning Unit	CALCULATION	ARITHMETIC		
FARM	Computers in the Curriculum	GAME	GEOGRAPHY	Yes	Yes
FISCAL	Computers in the Curriculum	SIMULATION	ECONOMICS		
FISH	Warwick Science Simulations	SIMULATION	GEOGRAPHY	Yes	
FORDER	School	SIMULATION	PHYSICS		
FRENCH	ITMA	PRACTICE	FRENCH	Yes	
GASCR1	Computers in the Curriculum	SIMULATION	CHEMISTRY		
GASCR2	Computers in the Curriculum	SIMULATION	CHEMISTRY		
GASDIF	Computers in the Curriculum	SIMULATION	PHYSICS		
GRAPH	Computer Based Learning Unit	CALCULATION	MATHS	Yes	Yes
GRAVITY	GAPE	CALCULATION	GEOGRAPHY		
GSTATS	Computers in the Curriculum	CALCULATION	GEOGRAPHY		
GUESS	Computer Based Learning Unit	GAME	ARITHMETIC		
HERED1	Computers in the Curriculum	SIMULATION	BIOLOGY	Yes	
HERED2	Computers in the Curriculum	SIMULATION	BIOLOGY	Yes	
HERED3	Computers in the Curriculum	SIMULATION	BIOLOGY	Yes	
HERED4	Computers in the Curriculum	SIMULATION	BIOLOGY		
HERED5	Computers in the Curriculum	SIMULATION	BIOLOGY		
HURKLE	GAPE	GAME	GEOGRAPHY		

PROGRAM	SOURCE	TYPE	SUBJECT	OF INTEREST	USED
INTRAD	Computers in the Curriculum	SIMULATION	ECONOMICS		
LATENG	Computers in the Curriculum	CALCULATION	CHEMISTRY		
LIQVAP	Central Program Exchange	CALCULATION	CHEMISTRY		
LUNCH	School	CALCULATION	BIOLOGY	Yes	Yes
MASPEC	Computers in the Curriculum	SIMULATION	PHYSICS		
MAXPRO	Computers in the Curriculum	SIMULATION	ECONOMICS		
MDROP	Warwick Science Simulations	CALCULATION	PHYSICS		
MILL	Computers in the Curriculum	SIMULATION	GEOGRAPHY		
MONPOL	Computers in the Curriculum	SIMULATION	ECONOMICS		
MOO	Computer Based Learning Unit	GAME	GENERAL		
MORPH	Computers in the Curriculum	CALCULATION	GEOGRAPHY		
MULTSC	Computers in the Curriculum	GAME	ECONOMICS		
ORBIT1	Computers in the Curriculum	GAME	PHYSICS	Yes	
ORBIT2	Computers in the Curriculum	GAME	PHYSICS		
OX30	Research Machines Limited	GAME	GENERAL		
PDP8	Computer Based Learning Unit	SIMULATION	COMPUTING		
PEND2	Central Program Exchange	CALCULATION	PHYSICS		
PEND3	Central Program Exchange	CALCULATION	PHYSICS		
PHOTO	Computers in the Curriculum	SIMULATION	PHYSICS		
PLACE	School	PRACTICE	REMEDIAL	Yes	Yes
POND1	Computers in the Curriculum	SIMULATION	BIOLOGY	Yes	
POND2	Computers in the Curriculum	SIMULATION	BIOLOGY		
POTTIT	Central Program Exchange	CALCULATION	CHEMISTRY		
PREDATOR	Warwick Science Simulations	SIMULATION	BIOLOGY		
PREY	Computers in the Curriculum	SIMULATION	BIOLOGY	Yes	Yes
PREYPRED	Improved version of PREDATOR	SIMULATION	BIOLOGY		

PROGRAM	SOURCE	TYPE	SUBJECT	OF INTEREST	USED
QSHFFL	Warwick Science Simulations	SIMULATION	PHYSICS		
RADACT	Computers in the Curriculum	SIMULATION	PHYSICS		
RAIL	Computers in the Curriculum	GAME	GEOGRAPHY	Yes	Yes
SCATTER	Central Program Exchange	CALCULATION	PHYSICS		
SELECT	Computer Based Learning Unit	SIMULATION	BIOLOGY	Yes	
STOIC	Central Program Exchange	PRACTICE	CHEMISTRY		
TABLES	Computer Based Learning Unit	PRACTICE	ARITHMETIC		
THOUSAND	School	PRACTICE	REMEDIAL	Yes	Yes
TRADE	Computers in the Curriculum	GAME	GEOGRAPHY		
TRANS	Computers in the Curriculum	CALCULATION	BIOLOGY	Yes	Yes
TRAWLER	Warwick Science Simulations	SIMULATION	GEOGRAPHY	Yes	Yes
VOCAB	ITMA	GAME	ENGLISH	Yes	

APPENDIX II

INFORMATION RECORDING

QUESTIONNAIRES/INTERVIEW SCHEDULES

APPENDIX II

INFORMATION RECORDING

Questionnaires/Interview Schedules:

Interview/Questionnaire One

Questionnaire One covered the teachers opinions and advice about the documentation and cataloguing system, with their general reasons for selecting and rejecting programs.

1. Is the cataloguing system for programs, and their use on the microcomputers satisfactory? Are there ways in which it could be improved? Please explain.

2. On each program, what data or content synopses or advice should be kept to inform new programs?

3. In choosing the programs for examination, what general factors influenced your selections? Why were some chosen and not others? what put you off selecting some of he other programs?

4. Of the programs catalogued in your subject area, what percentage did you decide to look at and run on the microcomputer?

Interview/Questionnaire Two

Questionnaire Two covered teachers' evaluation of programs which they had slected for inspection from the catalogue and program information, but which they had not yet decided to use in classroom teaching.

1. How suitable is the program content for integration within the school curriculum?

   Very suitable ---------- Unsuitable

   Comment:

2. How relevant is the content to the school curriculum?

   Relevant ---------- Irrelevant

   Comment:

3. How difficult do pupils find the topic in normal teaching?

   Very Difficult ---------- Very Easy

   Comment:

4. a) What particular features of the program made it valuable in understanding the teaching topic?

   b) Why and in what respects are these features valuable?

5. What features of the program do you consider to be undesirable and counter-effective?

6. For what age and ability range of children is the program suitable?

   Age:

   Low Ability ---------- High Ability

   Comment:

7. How easy was the program to use?

   Very Easy ---------- Very Difficult

   Comment:

8. How easy to understand were the program commands?

   Difficult ---------- Easy

   Comment:

9. How flexible is the program in dealing with different types of pupils, aims and teaching styles? Please explain.

10. Was the supporting documentation and materials supplied for the program adequate/inadequate? In what respects?

11. If you have rejected this program for use in teaching, what were your reasons for rejecting?

Interview/Questionnaire Three

Questionnaire Three covered evaluation of programs which teachers had decided to use in classroom teaching, including their reasons for doing so.

1. What particular features of the program or its content influenced you in choosing this program for teaching?

2. Are there any particular problems associated with teaching this particular topic?

3. What particular contribution do you expect the program to make? What are the advantages of using this program in the clasroom?

4. a) What type of teaching would you follow in using the program? (eg. Teacher demonstration/pupil group work/individual work).
   b) What influences you in making this decision?

5. How would you try to integrate the microcomputer materials within your conventional teaching of the topic?

6. How would you administer the computer teaching - how would it be managed, and what would the teacher and pupils be required to do?

7. What type of resource materials will be needed to support your use of the program?

8. What preliminary teaching, if any, would pupils need in order to manage the program?

9. How much (in hours) and what type of preparation would be required of the teacher?

10. What are the main disadvantages of the program, if any, which may counter effective learning/teaching?

Interview/Questionnaire Four

Questionnnaire Four was designed to obtain an idea of the lesson planning decisions which a teacher had to make when using computer based materials.

1. For this particular topic, what are your educational aims? What do you expect the pupils to know and be able to do after the lesson?

2. What particular teaching difficulties do you expect to encounter? What specific points will the pupils find particularly difficult to understand or to do?

3. What sort of teaching strategies, actions or decisions will you use in overcoming these difficulties, when teaching the topic to your class?

4. How will the computer program be used in the lesson - what type of teaching and teaching organisation will be adopted?

5. What extra preparation on the part of the teacher or pupil was required in order to make use of the program?

a) What resource material did you prepare?
b) What extra preliminary subject matter teaching (if any) did you undertake with the class?

Interview/Questionnaire Five

Questionnaire Five asked the teacher to evaluate lessons in which he had used computer based materials and equipment.

1.a) To what extent were the lesson objectives reached?
  b) What impressions/information/data led you to this conclusion.

2.a) Did the program and its workings meet expectations? In what ways?
  b) What impressions/information/data led to this judgement?

3.a) What were the good features of the program which helped its effectiveness in the classroom?
  b) What were the difficulties (if any) in managing the program?

4.a) If you were to use this program again, in what ways would the teaching be different? (What advice would you give to a teacher planning to use this program?)
  b) Would you use the program again in your teaching - or would you need extra provisions in the program?

Pupil Questionnaire

A typical pupil questionnaire took the following form:

1. Did the computer make the lesson more interesting? YES/NO

   If it did, in what ways?

2. What did you learn about <the subject> from the computer?

3. Was the computer better than a normal lesson in helping you to learn? YES/NO

   If it was, in what ways?

APPENDIX III

SUMMARY OF THE CLASSROOM INTERACTION SCHEME

APPENDIX III

SUMMARY OF THE CLASSROOM INTERACTION SCHEME

MODE	TYPE	SOURCE/ADDRESS
1. EXPOSITION/ DIALOGUE	1. EDUCATIONAL	1. TEACHER 2. CLASS 3. PUPIL GROUP
2. QUESTION	2. ADMINISTRATIVE	4. PUPIL 5. COMPUTER PROGRAM
3. ACTIVITY	3. OTHER	6. OTHER

Processing Levels Within Educational Interactions

A	ATTENTION	Simple question and answer with teacher/program direction of responses to material already displayed, i.e. response is essentially a copy response.
B	COMPREHENSION	Translation of information to obtain answers, i.e. response requires a semantic interpretation.
C	ELABORATION/ RELATIONSHIPS	Establishing relatonships between concepts or parameters within a context, eg. altering program parameters to achieve types of output or data patterns.
D	ELABORATION/ APPLICATIONS	Application to other contexts with the drawing of appropriate information from other contexts, eg. recognising implications of simulation data patterns for other situations. Testing What-If hypotheses.
E	ELABORATION/ GENERALISATION	Broader applications of relationships of principles to show extent of generalisation; the elaboration of knowledge with the introduction of one's own ideas and experience; being aware of limitations of simulation model - the limits of its generalisability.

...../Continued

F	CONSTRUCTION/ EVALUATION/ ORGANISATION	Application or construction of knowledge to form a judgement with reasoning, argument, and/or justification; equivalent to a re-programming or amendment of the operation sequence, or specification of the model to accomplish a goal.

ALSO RECORDED:

1. TIME	For sequences of interactions.
2. INTEREST	Class interest judged on a scale from 1 (low) to 5 (high).
3. COMMENT	Any useful comment on interaction, or the content of an interaction.